

An inaugural Essay  
on the  
Circulation of the Blood  
for the degree of  
Doctor of Medicine  
in the  
University of Pennsylvania  
by Joshua Rhoads  
of Pennsylvania  
Philadelphia Jan. 1828.

Memorial of the Board

of the City of

London

to the Hon. the

Commons of Great Britain

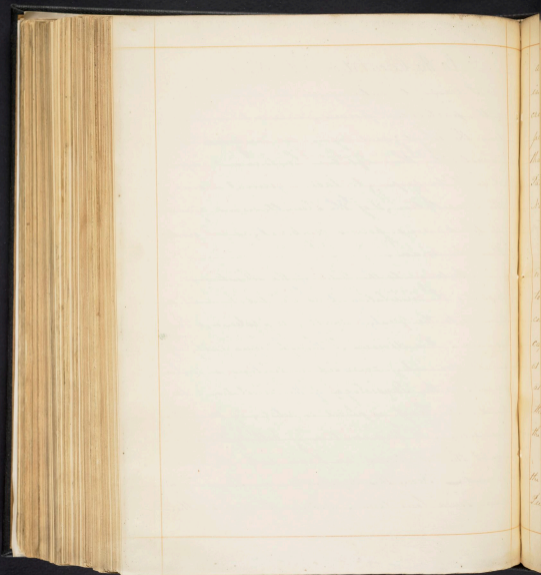
in Parliament assembled

Sheweth, That

## On the Circulation of the Blood.

Previous to entering, on the consideration of the particular powers, concerned in circulating the blood; and before we undertake to investigate their relative influence & importance; it will be proper, to take a general view of the circulation, & of the simultaneous operation of the various powers combined, as we find them in man.

Anterior to the time of the illustrious Bichat, the circulation was divided by most authors into the great, & small, or Systemic, & Pulmonary: this division, (though apparently of small moment,) exercised a deleterious influence, on the Physiology of the circulation: for by it, the Heart is placed in relief, by being the beginning, & termination of both systems; whilst the capillaries are thrown into the background — From this circumstance, Physiologists were for a long time, induced to overlook their

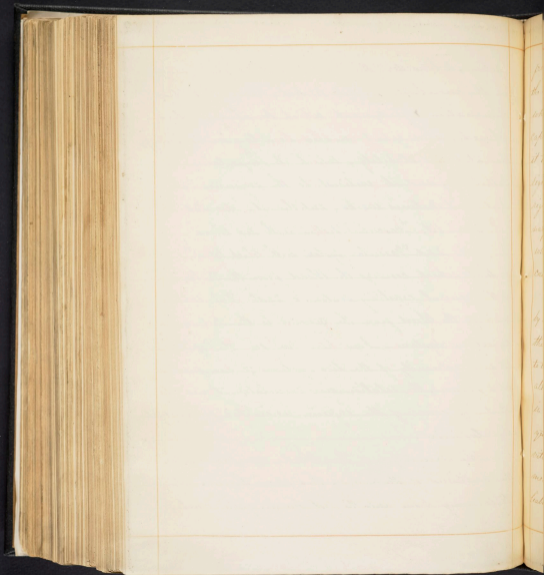


action, & consider the Heart, as the prime Mover in the circulation. But Richat, with that discrimination & judgment which he always displayed, and which enabled him to give Physiology, that station & stability, which its importance to Pathology, and its interest to the inquirer into Nature & Nature's works, entitle it; divided it into 1<sup>st</sup>. "Vascular system with Red Blood"

& 2<sup>nd</sup>. "Vascular system with Black Blood".

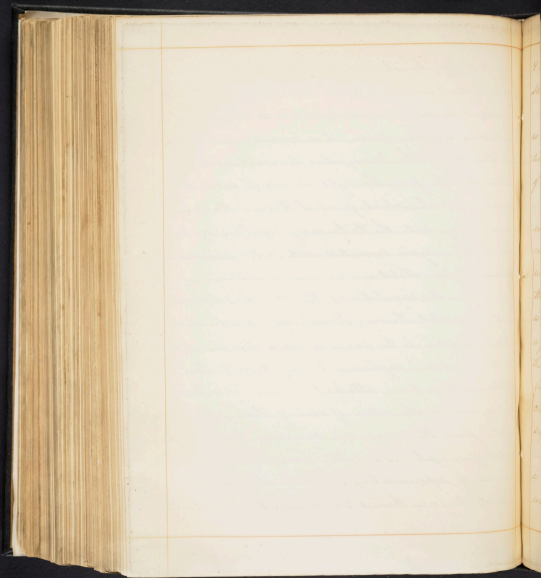
1<sup>st</sup> That which conveys the Blood from the Pulmonary to the general capillary system & 2<sup>nd</sup>ly. That which conveys the Blood from the general to the Pulmonary capillary system. Now here we see the Capillaries at each extremity of the two systems; we can perceive at a glance, the relation our circulation bears, to that, of some of the inferior animals: for example the caterpillar.

The circulation of Red Blood, commences in the capillaries of the Lungs, then flows through the Pulmonary veins into the left auricle of the Heart;



from the left Auricle into the left Ventricle; from  
the left Ventricle it is driven into the Aorta, through  
whose branches it is distributed to the general  
Capillary system, where it is converted into Black:  
it then enters the Veins, which transmit it to the  
right Auricle; from the right Auricle it enters the  
right Ventricle, which forces it through the Pulmo-  
nary Artery, into the Pulmonary Capillary system,  
where it is again converted into Red, & pursues the  
course before stated.

Since the circulation of the Blood was discovered  
by the immortal Harvey, Physiologists have directed  
their attention to the powers by which it is moved, &  
to their relative influence & Importance: But  
although they have attained a degree of certainty  
in regard to the action of some of these powers,  
yet (from the numerous variations to which the  
vital principle is subject, from our imperfect  
means of experimenting, & above all from our  
inability to form theories & opinions, we circulate

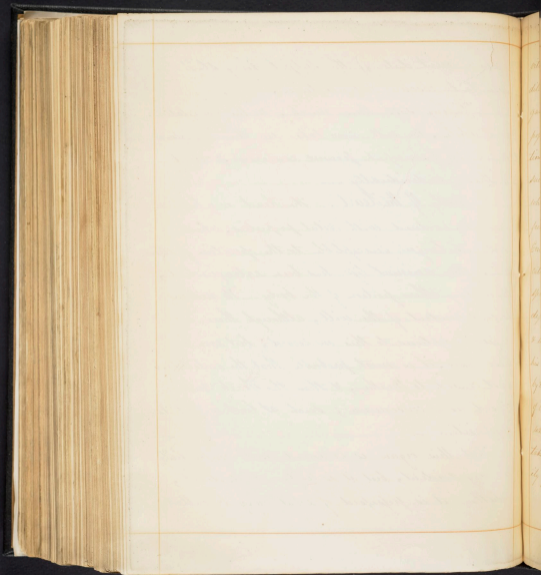


& insufficient data,) the subject may still be said to be obscure & uncertain.

Having said thus much, as to the circulation as a whole, we will now take up the consideration of the principal powers concerned, & treat of them individually.

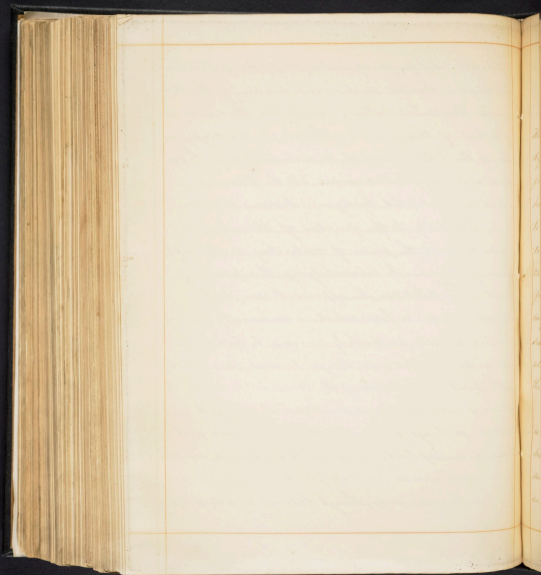
1<sup>st</sup> Firstly Of the Heart. The Heart is a hollow muscle, endowed with vital properties, which continue longer susceptible to the operation of stimuli, after animal life has been extinguished, than any other portion of the body. Its motion is independent of the will, although there are a few exceptions to this in record; but even in these cases, it is most probable that the individual first ceased to breathe, & then the Heart motion ceased as a consequence; such at least is Richer's supposition.

That this organ is endowed with contractility is very evident, but it is legitimate to doubt, whether it is possessed of what may be called



vital dilatability, is an inherent power of spontaneous  
 dilatation — Bichat in his consideration of the Or-  
 ganic Muscular System, concludes that it is  
 possessed of this power; although in his classifica-  
 tion of the Vital Properties, he does not acknowledge  
 such a power, but considers all the phenomena  
 which are exhibited by organic bodies, to proceed  
 from Sensibility to the operation of stimuli, and  
 Contractility or the power of contracting on the appli-  
 cation of these — In acknowledging this power of  
 spontaneous dilatation, he appears to me, to have  
 departed from a law which is universally receiving,  
 & which he was particularly anxious to impress on  
 his readers — "That, in things formed immediately  
 by the hand of the Creator of the Universe a simplicity  
 of causes will produce a multiplicity of effects;  
 whilst in things formed by the hand of man, it  
 takes a multiplicity of causes to produce a simpli-  
 city of effects" — It is I fear expressed it —

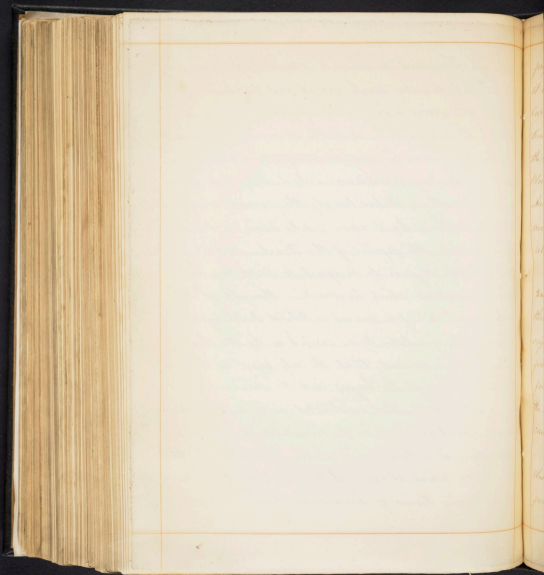
"In human looks, though labour'd on with pain,



"A thousand movements scarce on purpose going  
"In Gods, and single can it end produce,  
"Yet move to second in some other need.

That "Human nature is liable to err & wise men to differ in opinion," can never be more fully confirmed by any occurrence which may take place hereafter, than it has been by the various conclusions to which those have come, who have undertaken to estimate the power of the Heart - Whilst Boerhaave calculated its force to be equal to 100,000 lbs; Keil, from observations which he made, thought it was only equal to a few ounces - Whilst Dr. Harvey considered the circulation to be carried on by the Heart alone, others contend, that its only effect is to propel the Blood through the larger into the smaller Arteries.

All admit, that constituted as we are, the Heart is an essential agent in the circulation of the Blood; but there is a difference of opinion, in regard to the mode in which it exerts its power. Some consider it as a forcing Pump of immense power which

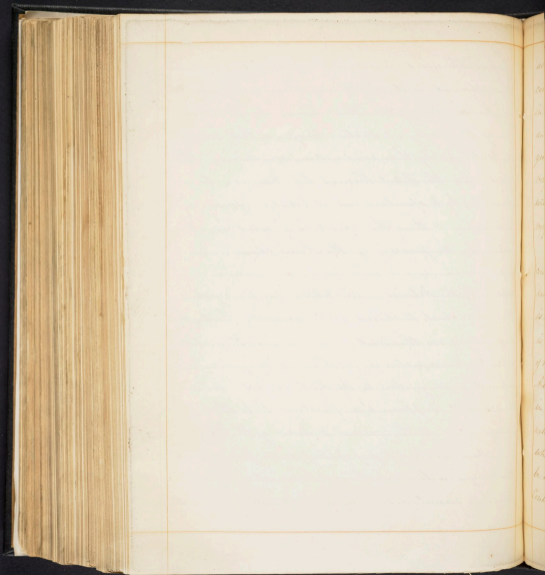


propels the Blood to all parts of the system, whence it is returned to the Heart, by the friendly aid of Capillaries, Veins, &c. Others think it is a combination of the forcing, & suction pump, & that whilst the Ventricles by their contraction, are driving the Blood from the Heart through the Arteries, the Auricles, by a spontaneous dilatation, form a vacuum, & thus the Blood is sucked in its return by the pressure of the Atmosphere. X

X  
Why  
not  
a note

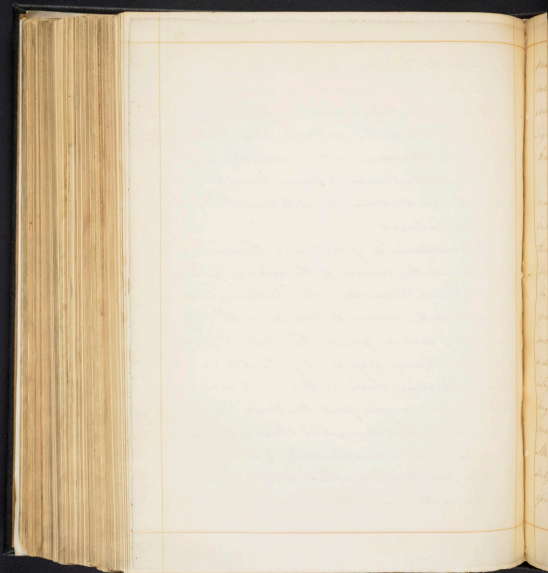
2ndly. Of the Arteries — The Arteries are the vessels through which the Blood flows from the Heart. They originate from the Ventricles, & derive their name from the circumstance, of their being generally found full of Air in the dead subject; whence the Ancients suppose their functions to be that of conveying Air to the various portions of the body —

They are tubes composed of such firmness and elasticity, as to retain their cylindrical form and pervious canal when empty. Extensibility is not



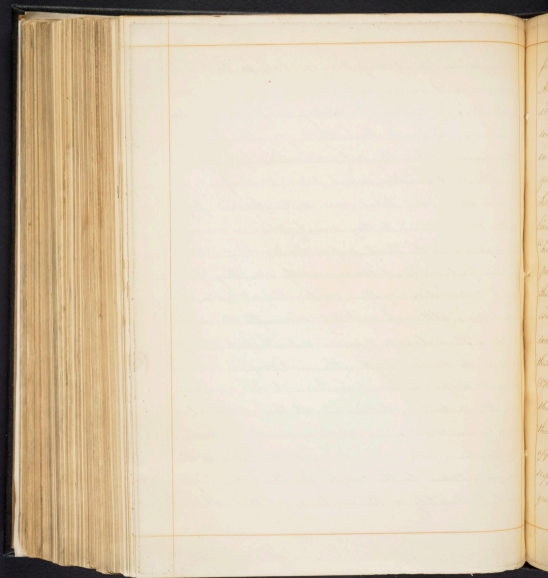
as evident as Elasticity, but that it exists to a considerable degree longitudinally, may be seen in taking up an Artery with a Pinaculum, & making an effort to extend it, you will find that it yields to the extension. — Transversely they possess very little, which may be shown by injecting them with water &c. &c. when you will find their caliber very little enlarged.

That contractility of texture, or the power of contracting on the absence of the extending cause, exists both in a transverse & longitudinal direction is very evident, as may be seen where the Pulse is small, from a greater than usual portion of the Blood having passed out of the Arteries, the Artery contracting closely on that which remains in it: hence we often find this Pulse in patients exhausted by Hemorrhage; & in states of the system where the Lymph is inadmixible: it may also be seen by puncturing an Artery between two Ligatures. Contraction in the longitudinal direction may be

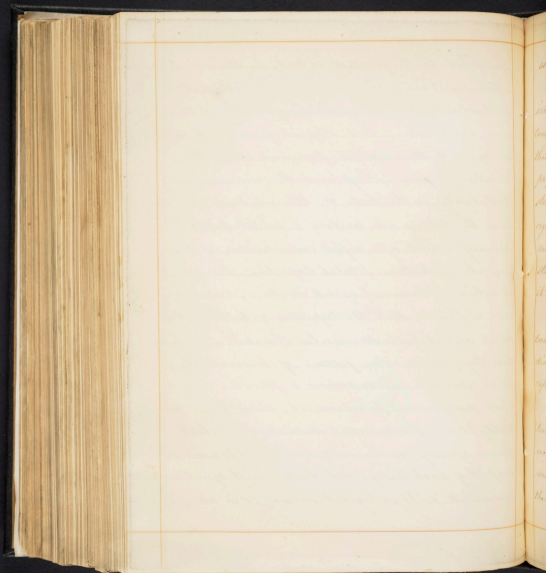


seen, when the Artery buries itself in the cellular membrane of an amputated stump - also more evidently, by cutting an Artery across between two Ligatures, as in Mr. Hennen's operation for Aneurism, when the cut extremities will separate.

The next question which presents itself for our consideration, is, what part do the Arteries perform in the circulation? Do they merely serve as canals through which the Heart propels the blood? or do they possess excitability, & consequently can they assist in its circulation by their contractions? Upon these questions, although agitated since the dawn of modern Physiology, & pursued with industry, & a desire to discover truth, the most eminent Physiologists differed, as much as Chemists do, concerning the nature of Caloric - whether material or merely an effect of an attractive motion in bodies. Mr. Hunter, after an arduous investigation of the subject, came to the conclusion that they possessed excitability or Muscularity, & that this



prevailed to the greatest extent, in the smaller  
 Arteries. Barhaard an equally intelligent &  
 industrious observer, also thought the Arteries  
 were muscular; but differed from Mr. Hunter  
 in regard to those which possessed it in the  
 greatest degree: He placed the maximum of  
 excitability in the Aorta, &c. Blumenbach also be-  
 lieves the Arteries are irritable; whilst Bichat  
 "himself a host" after a full consideration of their  
 properties of texture, Vital Properties, Diseases, &  
 the action of chemical agents on them, & a compar-  
 ison of these, with the Properties of texture, &c.  
 which appertain to Muscular structure, concludes  
 that they possess no one feature of Muscularity.  
 Where opinions are so various & opposite, how  
 shall we decide? by experiment, observation & au-  
 thority? but experiments & observations, which  
 appear equally conclusive, are brought forward in  
 support of each Theory; and Authors with equal ac-  
 quirements in Physiological science, and arrange



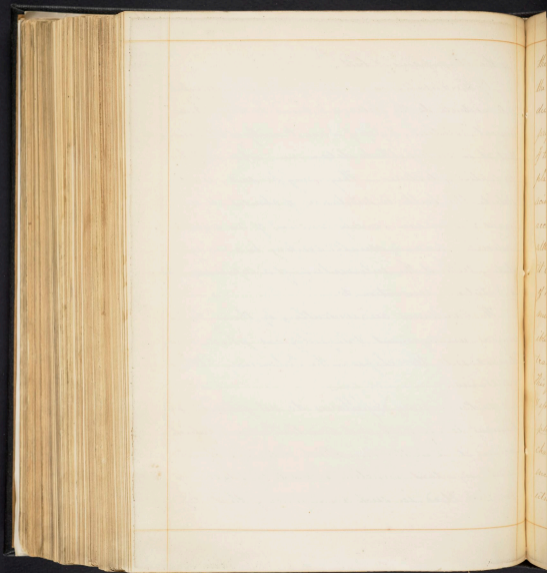
as the Champions of both. X

X  
arteries  
veins

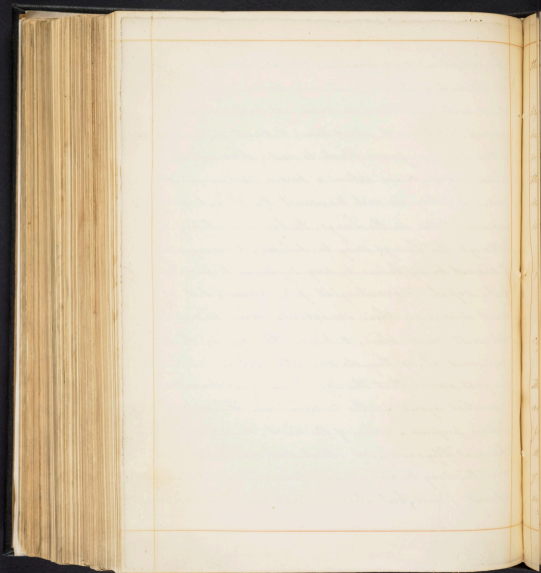
Of the Capillaries - The Capillaries, are vessels intermediate to the Arteries & Veins in their Anatomical Relation, & possess such brevity of Structure, that it is impossible to determine, what are their properties of texture - They may be said, to constitute the bulk or substance of almost all our organs; as we can scarcely conceive of an organic molecule (however small) existing in a living state, without the intervention of a capillary, for its Nutrition, renovation, &c.

The Capillaries are evidently, by their Anatomical arrangement & Physiological phenomena, divided into two classes - the Pulmonary & Systemic capillaries.

The Pulmonary Capillaries do not furnish nutriment to any part, not even the Lungs, which receive it from the Bronchial Arteries. Their most important function seems to be, to convey the Black Blood in such a manner, that by



the reception & elaboration of solid matter (by the contact of the Air), it may become red, & endued with properties suitable for sustaining the proper excitement, nutrition, & heat of the body. If this change from black to red, does not take place (as in cases when a person receives Carbonic Acid Gas), they do not transmit the blood, but it accumulates in the Lungs, Pulmonary Artery, &c. although the Lungs may be dilated; & consequently it cannot be explained by any supposed tortuosity of the vessels preventing its progress; but it must depend on their sensibility being incompatible with black blood, & hence they refuse to transmit it, as they do any other extraneous fluid. This fact shows that the Capillaries are important & essential agents in the circulation. The Hæmorrhic property, action of the Heart, &c. which Mechanical Physiologists attach such unlimited influence to, may be allowed full play, & to exert their utmost power, but still the Capillaries will overpower



them, & prevent the progreſſion of the Blood —

On the other hand the function of the General Capillaries ſeems to be to undo what the Pulmonary have been doing — it is in theſe, the red Blood parts & with the principles, it received in its paſſage through the Pulmonary Capillaries, for the Nutrition, &c. of the body, & is again converted into Black.

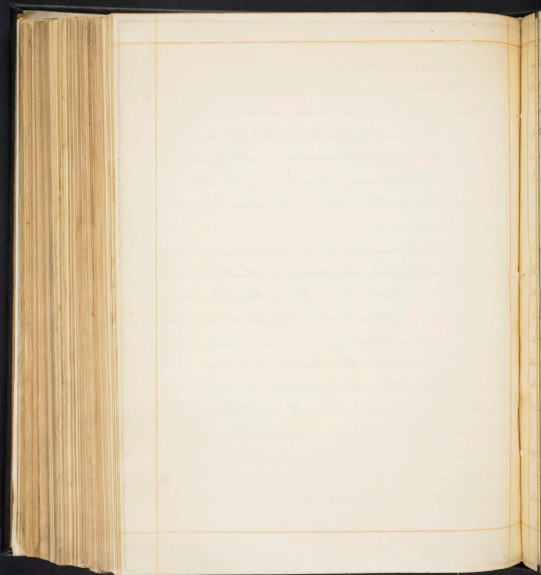
The blood may enter the Capillaries, from  
four cauſes — 1<sup>st</sup>. The Action of the Heart,

2<sup>nd</sup>. The action of the Arteries —

3<sup>rd</sup>. An absorbing power in the  
Capillaries themſelves —

& laſtly The Action of Gravity —

The firſt two of the above cauſes, ſam of opinion, are the efficient agents, when the vital powers and functions of the System are unimpaired; but when the action of the Heart has ceaſed, as a conſequence of death, the laſt two cauſes are the only agents; for we generally find the Arteries empty & pervious.



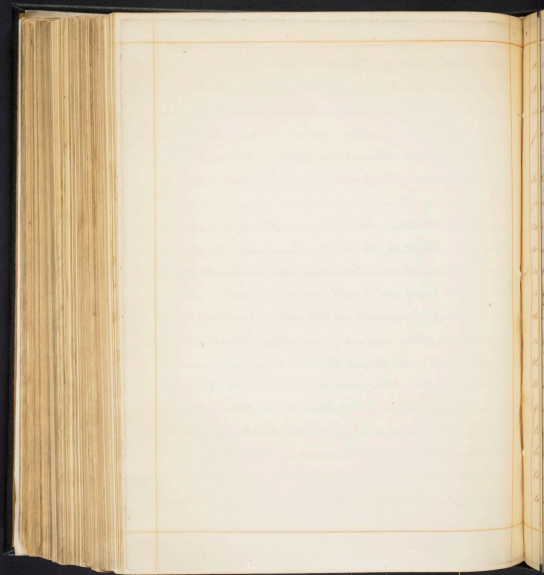
116.  
after death: hence they could exert no power in the  
last portion of Blood, which was in them.

The Blood having then entered the Capillaries,  
by the influence of these various causes & being  
in relation with their sensibility, causes them  
to contract regularly and propel it onwards -

Of the Veins - The Veins are the vessels which  
convey the Blood to the Heart. They originate from  
the Capillaries & anastomosing frequently with each  
other, terminate at length in the Auricles. The  
Veins which terminate in the left Auricle carry  
red blood; those which pour their blood into  
the right Auricle convey Black. Like all organic  
substances, the Veins are supplied with Arteries,  
veins, &c. for their Nutrition and renovation.

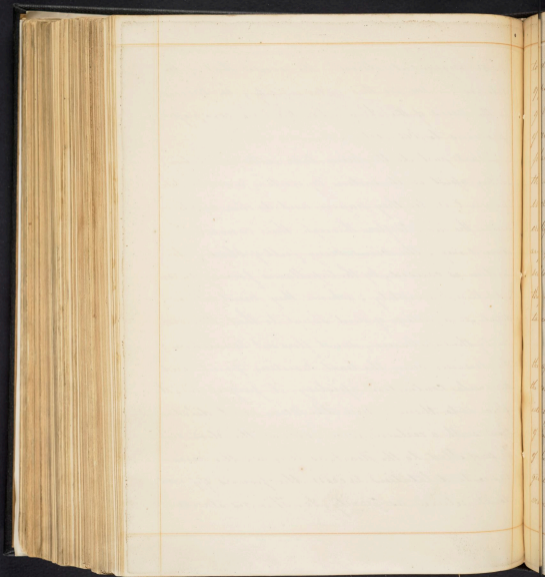
The Veins possess very little Elasticity, but are  
soft & loose like most other animal textures.

Extensibility is very great in a transverse  
direction & but slight in the longitudinal, in Veins;



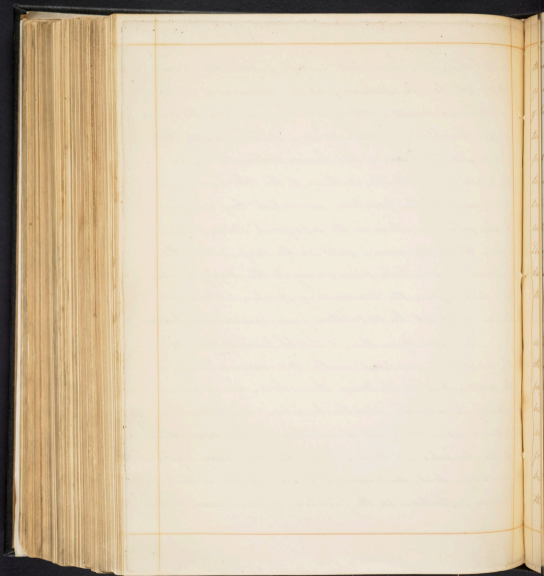
an arrangement directly the reverse that of the Arteries. — We see this extensibility, in Varices, in the Veins of the Arm when they are compressed previous to Amputation, &c. —

What part do the Veins take in the circulation? Do they assist in its motion by exerting a contractile power? or do they passiv and do other agents cause the Blood to flow through their canals? I would say, the Veins being full of blood, its motion is caused, by the Capillaries forcing in an additional quantity; whence they must either dilate, or a portion of blood equal to that thrown in by the Capillaries, must flow out somewhere; the Venicles being the least resisting point and Muscular contraction assisting its progression, it flows into them; now the Veins resist dilatation with a certain force, & hence the Blood will be propelled to the Heart, as long as, the resistance to dilatation exceeds the powers opposed to its return as Gravity, &c. This resistance



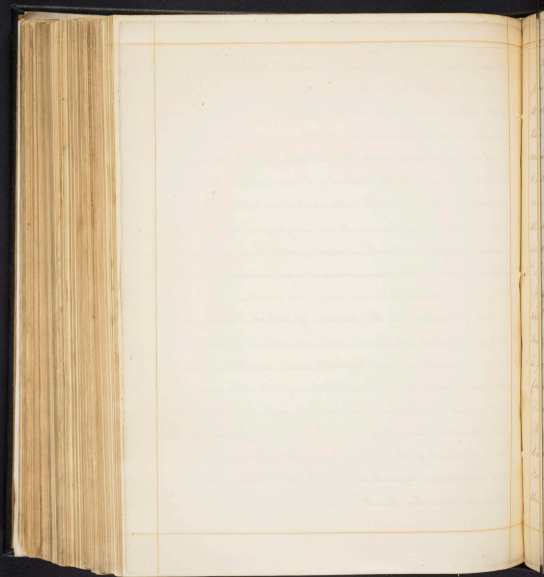
to dilatation), does not much exceed the power opposed to its return, as the numerous cases of Varicose veins, which we daily see in the wards of our Hospital, clearly prove. Varices mostly take place, in the Veins of the lower extremities, as the resistance to the motion of the Blood, is much increased by the position in which they are generally placed. It is in the superficial Veins particularly, that they occur, whilst in the deep-seated they seldom if ever take place, owing to the support which they derive from the surrounding parts, & the assistance rendered the circulation from Muscular contraction.

In order, before this, I should have spoken of the assistance rendered in the Venous circulation, by the contraction of the veins themselves, which are evidently Muscular, and the Arteries, & the contraction of these fibres may act as a valve, on the contraction of the Arteries, & thus prevent the Blood from regurgitating. Is it, an improbable supposition, that venous pulsation in the Jugulars, &c. may arise from



17.  
these fibres being palsied by some cause, & conse-  
quently on the contraction of the Atrium, a portion  
of the blood returns into the Veins, causing the pulsa-  
tion or rather distension of them, whilst another  
portion is forced into the ventricle? At the same  
time I throw out this hint, I am aware that this  
salutation is generally attributed to the blood meeting  
with some resistance to its passage through the  
Lungs; which I believe rests on a very firm founda-  
tion, but still there may be other causes & I think  
the former one.

In addition to the process of which I have particu-  
larly treated, there are several which Dr. Haüy and  
others consider of great importance, as Atmospheric  
pressure conjoined with dilatation of the Thorax, &c,  
but which I shall be content to pass over with the  
incidental mention I have made of them in the  
former part of this Thesis; for to use a vulgar  
but common expression, I think "they have ridden  
their hobbies too hard".



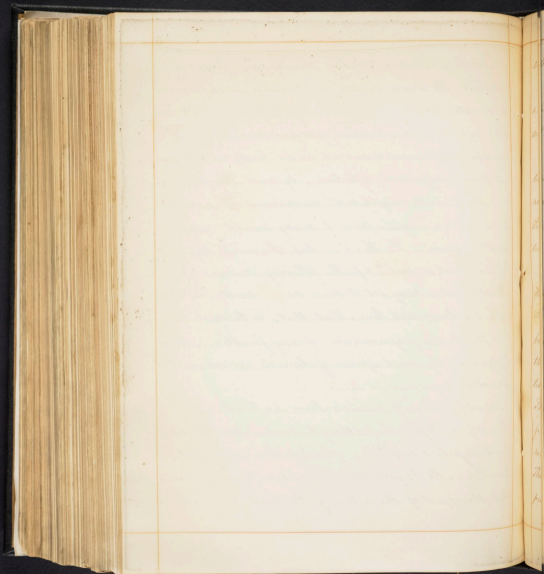
In the preceding part of this essay, I have explained the mode in which I conceive each power to operate in the circulation of the blood; & will now take up the consideration of a question, which I conceive has been determined in too hasty a manner, & without sufficient reflection, by most Physiologists - viz. What is the chief & most indispensable agent, in the circulation of the blood? many would answer with a shout - The Heart - but I would say - "Hold! not so fast!" & for the following reasons.

Firstly - we may set it down as an axiom, an inviolable & self-evident law, that that, is the most essential to the due performance of any function, which is proposed by most species of Animals exercising that function;

Secondly. Many animals have no Heart.

Thirdly. Vegetables (although endowed with distinct vessels & circulating fluids,) have no Heart.

Fourthly. All Physiologists of modern times agree, that the effect of the action of the Heart does not



extend to the Nerves.

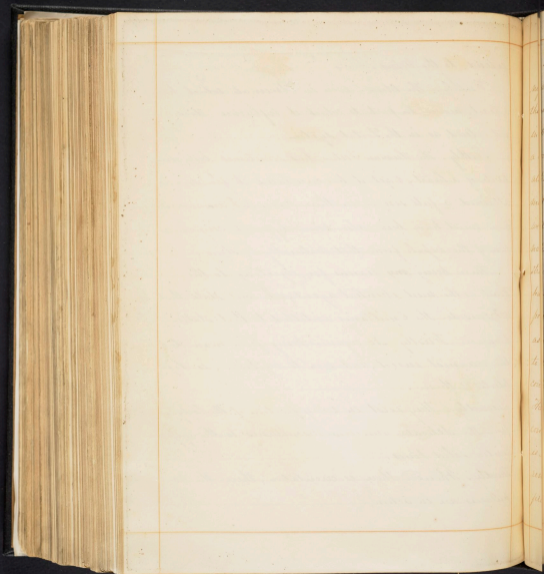
Fifthly. The blood, even in Animals which have a heart, moves in parts to which its influence does not extend as in the Visceral system.

Sixthly. The Human Fetus has sometimes been destitute of a heart, & yet it has circulated its fluids and attained a full size. In these cases I am aware, there must have been also some different conformation of the vessels from that naturally existing.

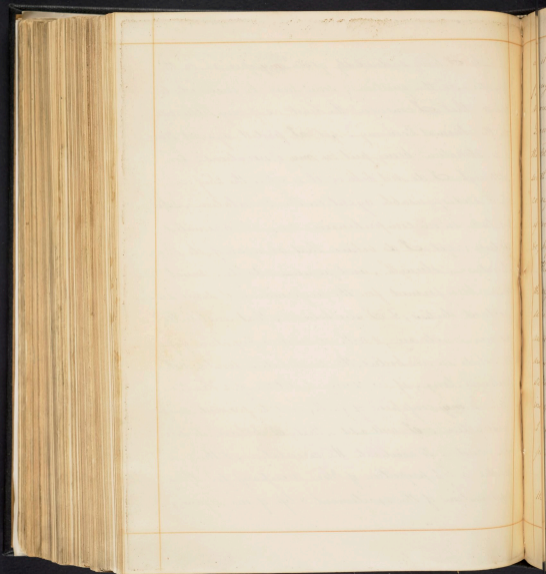
There being my reasons for objecting to the Heart as the most essential agent, I will state that I consider the Capillaries entitled to that station because Firstly. No organic being from man to the meanest insect, and even to vegetables, is destitute of them.

Secondly. They exist in every portion of the body, from the delicate Mucous Membranes to the apparently solid bones.

Thirdly. Wherever there is circulation, there the Capillaries are in action.



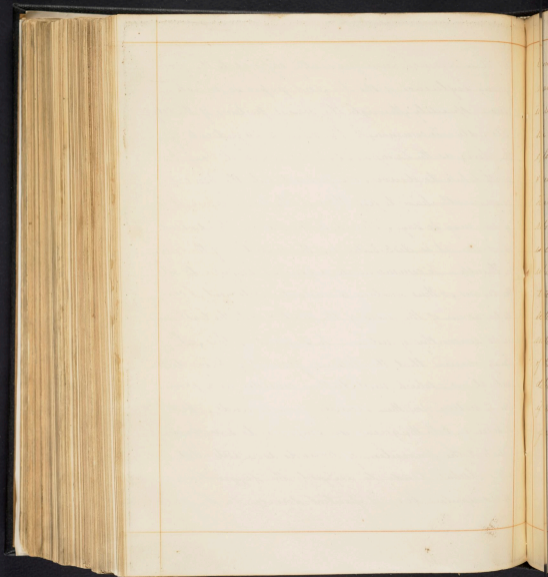
As I have so decidedly given my opinion in the negative, on this question, some may be inclined to think that I consider the Heart as of very little use in the Animal Economy: yet I protest against such a construction being put on my observations: for although I do not believe it is either the chief or most indispensable agent in the circulation, when we take in our comprehensive view all animated nature; yet I do believe that an organ of its size, structure, strength, and peculiar vitality, must have been formed for the performance of some important duties, & I also believe, that constituted as our vessels are, & with so small a proportion of fluids to solids in our bodies, the circulation would not continue long, if we were destitute of a Heart - This is my confession of faith, and to prevent misconstruction, I will add, that I believe its use is - First - To accelerate the circulation, & thus render a less proportion of Blood necessary for the preservation of the excitement & life of our organs,



as it is so much more frequently exposed to the purifying influence of the Air, and passes so much more speedily through the various portions of the body. Secondly - To convey the various ingredients of the Blood, as the Lymph, Chyle, &c; which it may be worth while to observe, are poured into the Veins & consequently have to pass through the Heart, where it is, if we may so say, stirred by the Valves, Chorda Tendi. &c, before it is distributed for the nutrition of the body.

Thirdly - To communicate a general impulse to all the organs, & thus sustain a constant excitement, I consider as one of the uses of the Heart & not the least most unworthy of notice - In support of this, I may observe that the Arteries generally have deep situations, which most Authors consider as a provision of nature for their security from wounds, but I believe both the giving an impulse to surrounding parts & the prevention of wounds were intended by it.

What tends to support the supposition of the impulse being of essential service in the animal



Economy is, that the Heart is attached to such a  
 muscle to the Aorta, that when it has contracted,  
 it recoils & communicates such an impulse to  
 the Aorta, so. that it can very evidently be seen  
 externally - now by the Laws of Mechanics - action  
 & reaction are always equal - consequently the  
 Heart receives as great an impulse of Blood as the  
 Aorta - We also see (when a portion of the Cranium  
 is removed) the Brain Pulsating from the impulse  
 which is communicated to it, by the alternate con-  
 traction, dilatation, & locomotion of the Arteries  
 seated at the base of the Cranium - Must not this  
 motion, perform some essential service in the economy  
 of the Brain? Would an organ of its importance &  
 delicate structure be subjected to such an impulse  
 if it did not assist in the performance of its  
 functions?

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